Design and implementation of a GIS-based accident management system using tracking technique

Abolghasem Sadeghi Niaraki*, Kyehyun Kim**

Abstract

This paper addresses a GIS (Geographic Information System) based system in order to reduce the rate of public transportation accidents occurring in Iranian roads network. Over the years, the road accidents are a major issue throughout the world. Today, particular consideration is given to those technologies which can lead to diminish in the number of critical incidents. One of the main factors resulting in accidents and fatalities rates growth is the speed violation of buses in Iranian road network. The conventional speed controlling approach in Iran based on the Tachograph which records vehicle's speed, time, and stoppage in the mechanical processing has many problems. Hence, this research is intended to design and implement a GIS-based system to manage road accident of Bus transportation system using offline tracking system. This was accomplished using a GIS-based technique that encompasses three steps. The first step is developing a GIS-based accident system. The second step includes designing and applying a tracking system inside 90 buses for recording Bus information for speed controlling. Lastly, by using mentioned system in police center, the illegal drivers' punishment would be considered properly. Overall, this system has been successfully applied in this work. Therefore, the police and transportation office are able to control and make policy to diminish the number of accident. It is anticipated that online tracking system through the Web GIS would be utilized in this system in the near future.

Keyword : GIS; bus; GIS-based accident management system; tracking system; speed controlling; police center; Tachograph

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* 인하대학교 지리정보공학과 박사과정(a-sadeqi@inhaian.net)

** 교신저자 인하대학교 지리정보공학과 교수(kyehyun@inha.ac.kr)

1. Introduction

The road accident on road safety is a controversial issue and a leading s. The burden of road traffic injuries in many low income countries is still unrecognized [6]. According to the police records, 74% of all accidents on the inter-city and inter-district highways in 1997 were due to driver behavior, with the remaining causes due to external vehicle defects. During 1998 the national newspapers reported a total of 32 major bus accidents resulting in 65 fatalities and 692 injuries of which 50% constituted single vehicle accidents [7]. Road safety is a major problem with today' s vehicular traffic [8]. Statistics reveal that a large number of people lose their lives in traffic accidents each year [9]. Injuries and extensive material losses are also associated with traffic events. For example, in the European Union alone, 9000 injuries were reported daily in 1999 [10]. Road traffic accidents are complicated to analyze they cross the boundaries of engineering, geography, and human behavior. It is not desirable to reduce the dimensionality of data through aggregation as statistical trends can be obscured, or even reversed [11].

Total Iranian road network excluding the village routes is about 72,766 kilometers including 4633 km of freeways and highways and 68,131 km of main roads and secondary roads. Traffic rates of various kinds of vehicles including shipment and commercial vehicles, public transportation vehicles and personal cars in these roads are different, however there were about 4 millions travels of transportation; passenger transition and personal vehicles in more than 1,050 routes have been reported in 2002 which is about 3,850 travels through each route in 24 hours a day. The passengers among different cities exceed 217,718,000 people in more than 12,815,000 trips. Considering the large volume of traffic in country's roads the rates of accidents occurring in these roads are relatively high. The rates of injuries and fatalities resulting from these accidents are in direct relation to the traffic rates in the routes and types of vehicles whereas the statistics of injuries and fatalities in 2002 exceeds 22000 killed and 131000 injured. These statistics have been growing by 10 percent each year [12].

Traditional speed control method is based on paper and mechanical system. Tachograph records vehicle' s speed, time, and stoppage rate through mechanical process. However, the conventional speed control approach for decreasing the rate of accident has many problems such as having mechanical errors, difficulty to control drivers' speed violation, including paper based data not GIS-based data, and involving complexity to use GIS-based accidental analyses. Lots of methods have been examined in order to reduce the rates of accidents and improving safety in the roads including geometric modification of the roads, constructing freeways and modification of high risk points. For

example, the First Responder Interactive Emergency Navigational Database (FRIEND) system is being developed to help manage the enormous amounts of information involved with accident management [13]. FRIEND supports several classes of users including first responders (workers in the field), field supervisors, dispatchers, and resource allocates. These users collaborate with the help of FRIEND to manage the information associated with an accident or accidents, including resource information, tasks and actions taken in response to an accident, geographical information, Emergency Operations Plan (EOP) information, and hazardous materials information. FRIEND is an example of a Cooperative Information Systems (CIS). In a CIS, multiple users view and modify a shared set of data. The users may access the data simultaneously or serially [14].

One of the main factors resulting in accidents and fatalities rates growth is the speed violation of buses as the main public transportation vehicle which disregarded the authorized speed limits and caused the death and injury of citizens. Hence, the objective of this research, in fact, is intended to design and develop GIS-based accident management system to keep under control of public transportation speed especially in Iranian inter-city road network. In this regards, first, the appropriate GIS-based road accident management system with various tools was developed. Second, in order to record bus information for speed controlling, a tracking system including many technical parts was designed and applied in side 90 buses between two biggest cities. Lastly, by implementing mentioned GIS-based accident system in police center, illegal drivers' penalties would be considered properly. This system was successfully implemented and tested in Iranian inter-city road network.

2. Materials and Methodology

Road Accidents are a major problem throughout the world. One of the primary causes of road accident is the speed violation of buses as the main public transportation vehicle. The digital era has brought with it a wealth of data stored in computer systems, pertaining to easy retrieval. Incident reporting systems are increasingly being recognized as offering analysts the capability to mine data for trends which may be subtly related, in the hope that reoccurrence of incidents can be reduced [15].

This research has been experimented to solve the mentioned problem of the in inter-city Iranian road network using GIS and GPS techniques based on the following procedure. First of all, a GIS-based accident management system has been designed and implemented with various GIS tools based on accident control tools for public transportation system in inter-city road network. Furthermore, a tracking system with several segments has been designed and applied inside 90 buses which traveling

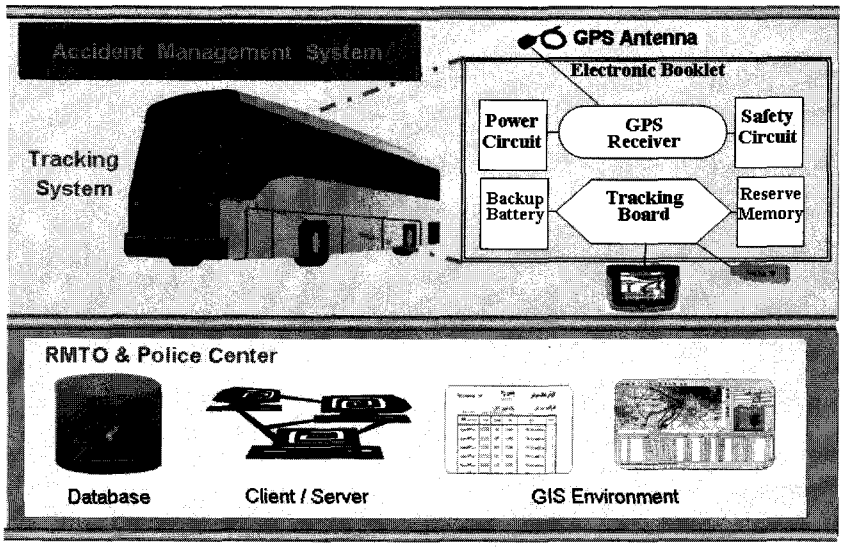


Figure 1 Two part of accident management system.

between the two biggest cities. Finally, the mentioned system has been successfully implemented in police station and transportation organization for 431 km Iranian intercity-road networks for speed controlling.

The drivers once refer to the police station of the original terminal and set up their USB memory, at that time all initial information as well as the driver' s picture will be stored in the USB memory digitally. The driver does not need to stop in the road police stations on their ways which result in decreasing travel time by one hour. After arriving the destination city and the destination terminal, the drivers bring out their USB memory and submit it to the police station of terminal and at that place the USB memory will be connected to the computer and its information will be downloaded on the computer.

Effective accident management requires the organization of large amounts of information. This information consists of reference information which rarely changes during an accident and decision support information which changes very rapidly. Much of the rapidly changing information is a result of collaboration between accident response personnel [13]. The computer is equipped with proper software and shows the bus traveling route on a digital map. Besides it shows the average speed of the bus in any point and the time that this speed has been recorded, the pattern of traveling (the bus route), time of stoppage on the way and also the geographic location of the stoppage points and the speed violations of the bus on its way. The authorized speed limits could be set up in this system and the times and places of speed violations

could be determined. More precise location data could help provide facts to guide programs including enforcement, education, maintenance, vehicle inspection, emergency medical services, and engineering to improve streets and highways [16]. The mentioned accident management system includes two important sections such as tracking system and GIS-based accident management system (Figure 1).

2.1 Tracking system

One of essential part of mentioned accident management system is tracking system that encompasses four parts: electronic booklet, GPS antenna, LCD display, and USB memory (Figure 1). This part is main part to collect spatial and non-spatial data regarding public transportation system (bus) attitudes in road network.

2.2 Electronic booklet

It is the main part of the system and should be installed in a place out of reach. Various circuits and boards includes tracking terminal, GPS receiver, tracking board, power circuit, safety circuits, backup battery and a reserve memory are housed. The necessary power is provided by bus with 12-24 volt power battery and a back-up battery has been housed in the storage too (Figure2).

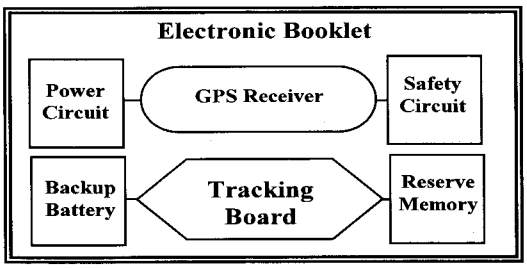


Figure 2 Several parts of electronic booklet.

2.3 GPS antenna

GPS antenna which has 1 cm thick and 2 cm long is installed magnetically on the top of the car. It should be considered that the antenna should be open to the sky to receive the signals from the satellites. Positional dimensions are computed by the receiver in Earth-Centered, Earth-Fixed X, Y, and Z coordinates [17].

2.4 LCD display

This display is used to demonstrate the information to the driver. Position, speed and other necessary information are shown to the driver through the displaying. The driver should pay attention to possible alarms shown on this screen in order to avoid any problem. This display should be installed in a manner that the driver and all passengers could see all details easily so that they could be aware of the travel situation and/or possible violations. The validity of identification and authorization of driving of bus driver, correct operation of device and the USB memory, and possible violations of driver will be shown on the display.

2.5 USB memory

All the information about the speed, geographic position, time, stoppages and direction of public transportation vehicle would be received from GPS in predetermined time intervals and stored in the memory. The USB memory is a memory card or Flash RAM to be submitted to the drivers and their personal specifications have been stored on it. The travel information will be stored on the memory hereby. Various information regarding drivers and vehicle could be stored on this memory or on the main terminal.

3. GIS-based accident management system

Highways and transportation engineers rely heavily on GIS instead of paper maps which our predecessors have used for centuries. While there is a certain comfort from having a record system containing large numbers of paper maps with highways data marked on them, such systems have serious disadvantages and hidden cost [16]. GIS is an emerging technology that has evolved very rapidly in the last decade. GIS systems have been used by a variety of institutions such as governmental organizations and universities and also by companies and multinational corporations [18, 19, 20].

This convenient and comprehensible way of merging diverse information supports the development of effective solutions for complex problems [21]. Many highway agencies have been using GIS for analyzing accident data. Identification of problematic locations is one of the most important aspects in accident studies. The GIS based application combines the information collection capabilities with the visualization. The GIS and Road Accident View System are a set of applications developed for managing accident database entries [16]. The reason behind this spectacular evolution is that GIS is a technology that provides means for integrating geographical data and other kinds of information [20]. There are several kinds of GIS process and analyses have been performed after transferring all information of bus drivers and bus from tracking system. These analyses show the capability of the new method comparing with the old method, application of mechanical Tachograph. GIS-based accident environment includes various parts of the program designing database sections, speed analyses, unauthorized stoppage analysis, authorized route of travel, bus travel simulation, analysis of time of travel (Figure3).

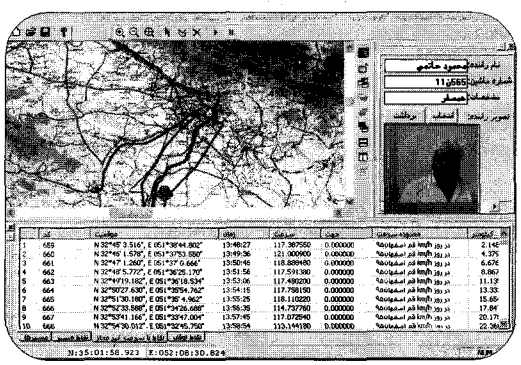


Figure 3 Interface of accident management system.

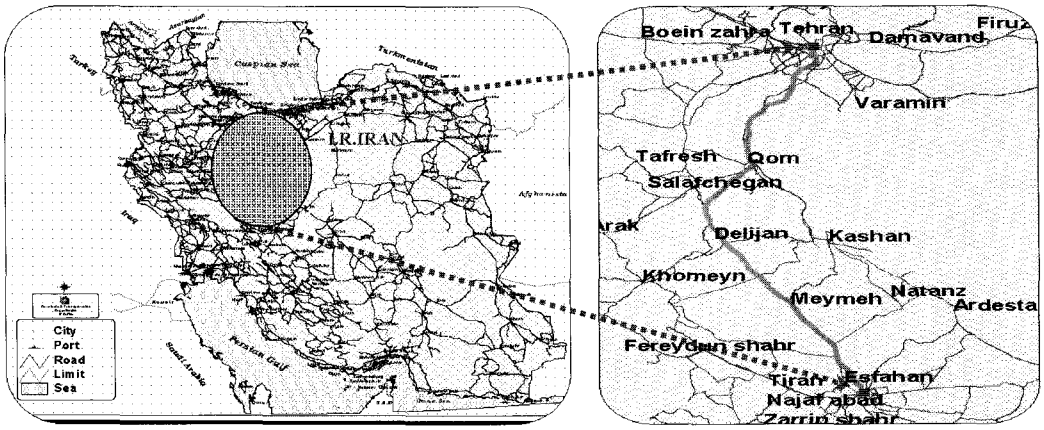
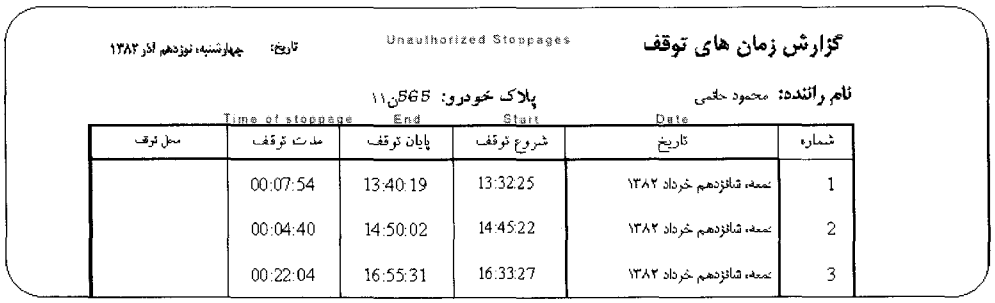


Figure 4 Study area connecting the two largest cities (431 km).

3.1 Designing database sections

The database section is one of the major parts of accident system to store and manage data for proper decision making. This database can be composed of drivers' specifications (picture, personal specification, professional background, records of crimes and violations) and vehicle's specification (technical specification, plate number, technical transactions, records of mechanical repairing, tolls and liabilities, information of bill of lading and the passenger transition company). By using this new system, a versatile database of passenger transit fleet and drivers could be developed.

The road maintenance and transportation organization of Iranian Road Ministry has collected spatial and non-spatial data at scale of 1:250000 through the implementation of "identification project of roads and other marginal constructions" via GPS including the road network (type of road, year of structure, layer' s material, etc.), technical contracture near road (bridge, tunnel, wall, etc.), and other features surround the road such as facilities (fuel



گزارش زمان های توقف Unauthorized Stoppages

تاریخ: چهارشنبه، نوزدهم آذر ۱۳۸۲

نام راننده: محمود حاتمی پلاک خودرو: ۵۶۵ن۱۱

شماره	تاریخ	شروع توقف	پایان توقف	مدت توقف	محل توقف
	Date	Start	End	Time of stoppage	
1	نمعه، شانزدهم خرداد ۱۳۸۲	13:32:25	13:40:19	00:07:54	
2	نمعه، شانزدهم خرداد ۱۳۸۲	14:45:22	14:50:02	00:04:40	
3	نمعه، شانزدهم خرداد ۱۳۸۲	16:33:27	16:55:31	00:22:04	

Figure 5 Report for unauthorized stoppage

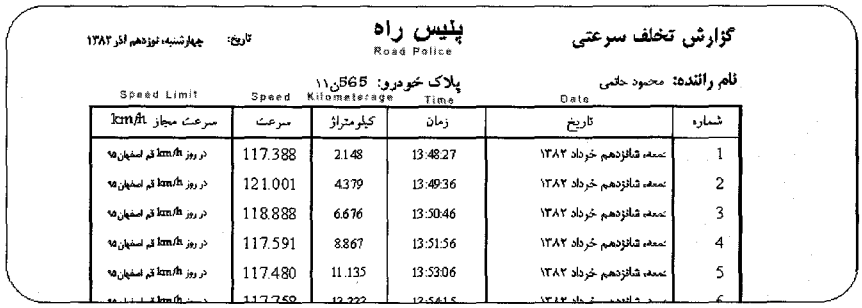


Figure 6 Police report regarding all driving information regarding driving

station, public center, etc.), touristy feature (sea, jungle, etc.), weather, and road traffic. This research has been implemented on the 431 kilometer inter-city routes of the two biggest cities in Iran, Tehran and Esfahan (Figure 4).

3.2 Analysis of unauthorized stoppage

The unauthorized stoppages are one of the main factors results in high rate of road accidents, heavy traffics and risk creation throughout the routes. There was no way to identify these unauthorized stoppages in the traditional systems but in this new system these violation could be tracked and proper punishments could be considered (Figure 5).

3.3 Analysis speed of vehicles

Apart from general GIS tools in accident management system there is one especial part for speed analysis. The collected information from GPS is based on the series of positional points such as distance and time of travel, speed, direction the distance from the point of origin. Speed limit in night and day is normally determined on police center rules regarding the type of road and other parameters. Therefore, considering the type and situation of the routes, the recorded points with higher speed rates than the determined limits will be verified. The program enables the user to analyze those high speed points with additional GIS information on the map to find out why the bus has increased its speed rate in these mentioned points (Figure 6).

3.4 Bus travel simulation

The capability of simulating bus travel throughout the route on a digital map uses the information like the real time speed, the distance from origin and the time which is one of the significant features of this system. This capability of travel simulation enables the authorities to investigate the traveling of vehicles in every moment without physical existence of buses and take proper action to resolve the problems which exist in the

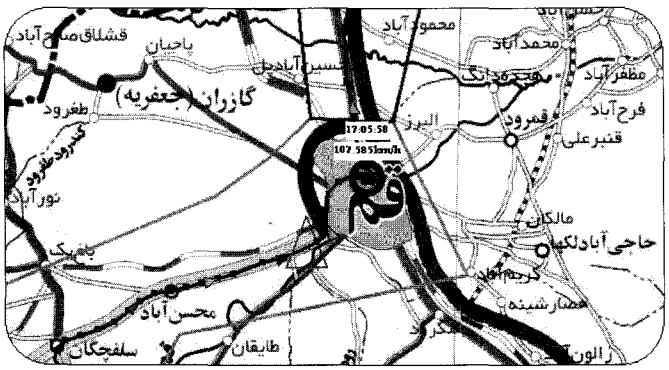


Figure 7 Simulation of traveling from origin to destination.

routes and reduce the rate of road accidents (Figure 7).

3.5 Analysis of time of travel

The ability of analyzing the time of the bus's travel is another tool of this system. In this regards, in the basis of this analysis if the driver has violated the authorized time limit he will be fined. It would be proper tool for Defining new Standard for Authorized Time Limitation. The Collection of the travel time of buses helps the authorities to update the determined time limits of travel for various routes of roads network, according to the archived information from the analysis.

3.6 Analysis of authorized route of travel

There is one inevitable tool to control passenger vehicles under the GIS environment. The series of authorized travel routes have been defined in this regards. The system will send alarms in case those vehicles enter in or get out of the predetermined travel route automatically. Through the definition of these authorized travel routes, some violations including the traveling of bus drivers in unauthorized directions in order to handle their personal affairs without respecting to the passengers' rights, could be prevented.

4. Conclusions

This research addressed that traditional technique lacks of capability to manage public transportation accident. While, the GIS-based accident management system can collect various spatial and non-spatial data to develop more efficient and appropriate buses' speed control system for reducing accidents occurring due to speed violation. This methodology can be of assistance of police and transportation organization in order to perform more careful control over the buses travels. It also leads the drivers to go on more certain speed rates without unnecessary stoppages on the way for time records.

More specific advantages of this system comparing with traditional tachograph machines can be listed as follows. Firstly, it makes a relation between geographic positions and specifications of travel. Secondly, all the violation records can be transferred to traffic and police database thereby managing information and getting necessary reports become possible. Thirdly, this system is not dependent on internal systems of vehicles, which can avoid the possibility of data manipulation. Lastly, since all information can be recorded and stored in the computerized system with accurate information, useful information and statistics on the basis of individual events become possible for more effective traffic management. It is also anticipated that the installed device in the vehicle can be used as a black box, which can lead to provide latest information regarding the situation, speed, driver specification, route and travel specification, etc. same as the one used in the aircraft.

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Abolghasem Sadeghi Niaraki

1999 Department df Geodesy and Geomatics Engineering, K.N.Toosi University of Technology(BSC)

2002 Department of Geodesy and Geomatics Engineering, K.N.Toosi University of Technology(MSC)

Research interests : Web GIS, Mobile GIS, Ubiquitous GIS, and SDI

Kyehyun Kim

1982 Department of Resource Engineering, Hanyang University(BSE)

1989 Department of Hydrology, University of Arizona(Tucson)(MSC)

1993 Department of Civil and Environmental Engineering, University of Wisconsin (Madison)(PhD)

Research Interest : GIS application for water resource management, environmental management, facility management, and disaster prevention; Ubiquitous GIS development; GIS standardization.